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Between Food and Fuels: The Importance of Balancing Dual-Edged Sword of Palm Oil Usage

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Abstract

The versatility of palm oil, especially in culinary goods and sustainable energy, has elevated it to a crucial position in international trade. The dual role of palm oil presents a complex challenge, managing the surge in demand for edible oils while addressing the heightened focus on sustainable fuel alternatives. This study aims to comprehensively examine the multifaceted implications of palm oil usage by synthesizing existing knowledge on its economic, environmental, and social impacts. Using a qualitative literature review method, this research systematically analyzes over 80 scholarly articles to explore the interconnected benefits and compromises of utilizing palm oil for nutritional and energy purposes. Data collection was conducted through rigorous database searches across multiple academic platforms, focusing on peer-reviewed publications. Thematic content analysis was applied to identify key themes and patterns related to production growth, market dynamics, environmental sustainability, and socio-economic factors. The findings indicate that palm oil production has expanded significantly, influencing global vegetable oil markets and biofuel sectors. Nonetheless, this progress often results in environmental degradation, notably through deforestation and the emission of greenhouse gases. Socially, palm oil cultivation supports millions of livelihoods, although benefits are unevenly distributed, particularly among smallholders. The review highlights the urgent need for integrated governance frameworks and sustainable management practices to reconcile competing demands. In conclusion, a balanced approach to palm oil utilization is essential to mitigate negative consequences and enhance benefits across sectors. The study recommends future research to focus on empirical policy evaluations and the development of innovative sustainability solutions to support effective decision-making in palm oil management.

Keywords: Biofuel, Food security, Palm oil, Qualitative literature review, Sustainability.

1. Introduction

Recognized for its economic importance and widespread application, palm oil has established a dominant presence in both international food industries and renewable energy sectors. Its global consumption has surged dramatically over recent decades, primarily due to its adaptability, cost-effective production, and superior yield in comparison to alternative oil-producing crops (Murphy et al., 2021). Serving diverse industries, palm oil contributes significantly to food processing, personal care, and pharmaceutical manufacturing, solidifying its role in common household commodities (Alhaji et al., 2024). Concurrently, its increasing adoption in the bioenergy sector reflects a broader push by nations aiming to meet sustainable energy goals and lower their GHG outputs (Prananta & Kubiszewski, 2021).

The dual utilization of palm oil across the food and renewable energy sectors has given rise to multifaceted sustainability concerns. Despite its benefits for food supply and economic growth, its application in biofuel has intensified debates over land conversion, environmental impacts, and the tension between fuel and food priorities (Subramaniam et al., 2020). With bioenergy strategies gaining momentum across both industrialized and emerging nations, the allocation of palm oil towards energy uses can potentially exacerbate food insecurity and create unintended socioeconomic consequences (Ji & Long, 2016).

At the heart of the debate lies the "dual-edged sword" nature of palm oil: its ability to simultaneously serve as a solution for clean energy and a potential contributor to deforestation, loss of biological diversity, alongside elevated greenhouse gas outputs (Danylo et al., 2020). This dual role is further intensified by international trade dynamics, investor interests, and governance structures that tend to emphasize short-term economic advantages at the expense of long-term sustainable development (Schleifer & Sun, 2018). Such tensions underscore the importance of critically evaluating the regulation and oversight of palm oil production and distribution at the worldwide and regional tiers (Grabs & Garrett, 2023).

In regions like Southeast Asia, especially Indonesia and Malaysia, palm oil is not merely an export commodity but also a vital part of rural livelihoods. Providing livelihoods for countless small-scale farmers, it has also played a crucial role in diminishing rural poverty (Chrisendo et al., 2022). Nevertheless, transforming land into oil palm

plantations sometimes occurs at the potential cost of forest habitats, marginalizes indigenous communities, and threatens biodiversity hotspots (Dislich et al., 2017). Furthermore, expansion driven by bioenergy demands may deepen these trade-offs, making the food-energy-environment nexus more fragile (Darmadi et al., 2023).

From an environmental standpoint, extensive monoculture plantations dedicated to palm oil cultivation have been unfairly associated with widespread deforestation, peatland degradation, and increased carbon emissions, all of which counteract the very purpose of climate-friendly energy policies (Manik & Halog, 2013). Furthermore, the greenhouse gases emitted during the entire production and use cycle of palm oil biodiesel, when including indirect land use change, can sometimes exceed those of fossil fuels (Amri et al., 2023). These findings challenge the prevailing narratives that position palm oil as a "green" energy alternative and emphasize the need for more nuanced assessments (Purnama et al., 2025).

Socioeconomically, the promotion of palm oil for bioenergy can generate employment and infrastructure development, but may also induce potential land conflicts, deepen income inequality, and diminish food accessibility if not managed with proper inclusive governance (Herdiansyah & Majesty, 2024). Issues such as land tenure insecurity, weak institutional oversight, and lack of smallholder support further complicate the promises of sustainable practices from the palm oil production industry (Putra & Elida, 2024).

Conversely, palm oil continues to play a vital role in the worldwide food supply chain. As one of the most efficient oil crops, it fulfills more than a third of the worldwide demand for vegetable oils while occupying under 10% of the agricultural land allocated to oilseed cultivation (Barrett et al., 2022). Disruptions along the supply chain can result in volatile prices and influence the cost accessibility of food products, particularly in low-income countries (Ayompe et al., 2021). Therefore, calls to eliminate palm oil entirely due to its environmental consequences may inadvertently harm food security and economic resilience in vulnerable regions (Azhar et al., 2017).

To reconcile these conflicting realities, scholars and policymakers have advocated for the implementation of environmentally responsible palm oil methods, including certification schemes such as RSPO, ISPO, and MSPO (Abdul Majid N., 2021; Schmidt & De Rosa, 2020). While such frameworks offer pathways toward mitigating environmental damage and promoting fair labor practices, their implementation remains inconsistent and often lacks enforcement mechanisms. Moreover, the market uptake of certified sustainable palm oil remains limited, raising questions about the effectiveness of voluntary compliance in transforming the industry.

Given the globalized nature of the palm oil trade, any effort to address its dual role must consider multi-scalar governance structures that link producers, traders, governments, and consumers. This includes rethinking land use policies, incentivizing agroecological transitions, and integrating food-energy-environment considerations into international climate agreements. Furthermore, it requires an ethical and evidence-based approach to balancing trade-offs between development objectives and planetary boundaries.

This paper aims to explore how palm oil's dual functionality as both a food source and a biofuel feedstock presents challenges and opportunities within the broader sustainability discourse. Using a qualitative literature review approach, the paper critically synthesizes existing academic and policy-related literature to map the trade-offs, interdependencies, and governance gaps surrounding palm oil usage. The aim is to offer an in-depth insight into managing the intricate challenges of food-versus-fuel conflicts within palm oil systems, guiding future studies and policy decisions.

2. Literature Review

2.1. The Rise of Palm Oil in Global Commodity Systems

Palm oil production and consumption have surged dramatically in recent decades, emerging as a strategic global commodity. Its high yield, low cost, and versatile application across various industries have contributed to its dominance in global vegetable oil markets (Shigetomi et al., 2020). Present in nearly half of all packaged supermarket products, palm oil is central to food security for both producing and importing nations (Adade, 2022). Its rise, however, is not merely a result of agricultural efficiency but also of global trade liberalization and targeted investment policies in Southeast Asia, particularly Indonesia and Malaysia (Husin et al., 2023).

2.2. Palm Oil as a Dual-Use Resource: Food and Fuel

Palm oil's dual-use nature—as both a food product and a biofuel feedstock—places it at the intersection of two major global systems: energy and agriculture. This duality has given rise to the food-versus-fuel debate, where the increase in palm oil production for biofuel may compromise both the availability and accessibility of food (Hasudungan et al., 2024). Proponents argue that biofuels offer renewable alternatives to fossil fuels and present rural development opportunities, while critics point to displacement of food crops, land grabbing, and volatility in food prices (Marin-Burgos & Clancy, 2017).

2.3. Land Use Change and Environmental Trade-Offs

One of the most contested consequences of palm oil expansion is its role in land use change. Forest conversion into oil palm plantations is a leading cause of deforestation in tropical regions, leading to biodiversity loss, deterioration of peat soils and notable emissions of greenhouse gases (Saswattecha et al., 2016). Despite its higher land-use efficiency relative to other oil-producing plants, the environmental costs are magnified by unsustainable practices and weak enforcement of land governance (der Laan et al., 2017). The indirect land use change associated with increased demand for biofuels further exacerbates carbon emissions and ecological fragmentation (Petrenko et al., 2016).

2.4. Socioeconomic Dimensions: Between Empowerment and Marginalization

The socioeconomic impacts of palm oil are multidimensional. In producer countries, palm oil provides employment opportunities, supports rural infrastructure, and contributes to poverty alleviation (Tuslian, 2021). However, these benefits are not evenly distributed. Small-scale farmers frequently encounter systemic obstacles, including limited access to financial resources, dependence on middlemen, and exclusion from premium markets

due to certification costs (Berenschot et al., 2024). Moreover, land tenure insecurity and elite capture of plantation benefits have led to increased inequality and social conflicts in various regions (Grasse, 2022).

2.5. Food Security Challenges and Market Volatility

The allocation of palm oil towards bioenergy may intensify food security challenges, primarily affecting developing and middle-income countries. Studies show that increasing demand for palm-based biodiesel can lead to reduced availability of cooking oil and increased domestic food prices VV(Naylor & Higgins, 2018). As palm oil becomes commodified under both energy and food markets, its price volatility can disrupt national food strategies and strain household purchasing power (Bergmann et al., 2016). This dynamic underlines the need to carefully evaluate energy diversification policies within the broader context of food system resilience (Caniato et al., 2017).

2.6. Certification and the Push for Sustainability

In response to sustainability concerns, voluntary certification programs like the Roundtable on Sustainable Palm Oil (RSPO), Indonesian Sustainable Palm Oil (ISPO), and Malaysian Sustainable Palm Oil (MSPO) have been established to promote adherence to environmental and social criteria (Markne, 2016). While these initiatives represent progress, their impact remains limited due to challenges in traceability, enforcement, and market acceptance (Ramli et al., 2020). Critics argue that the effectiveness of these schemes is hindered by corporate greenwashing, limited participation of smallholders, and the lack of robust third-party auditing (Dauvergne, 2018).

2.7. Governance and Policy Gaps

The regulatory structures managing palm oil production and market activities remain inconsistent and scattered. At the national level, inconsistent policy objectives—ranging from export promotion to food sovereignty and climate mitigation—often result in regulatory contradictions (Choiruzzad et al., 2021). Internationally, the absence of binding multilateral agreements on palm oil sustainability contributes to regulatory loopholes and competitive deregulatory pressures among producer countries (Pacheco, Pablo; Schoneveld, George; Dermawan, Ahmad; Komarudin, Herry; Djama, 2020). Effective governance must address these gaps through coherent policies that balance economic development with environmental integrity and food justice (Schouten & Hospes, 2018).

The reviewed literature indicates that palm oil occupies a complex space within the global sustainability agenda. While it offers economic and energy benefits, its unchecked expansion raises critical concerns related to environmental degradation, food insecurity, and governance failures. Addressing the dual-edged nature of palm oil requires systemic change—one that integrates ethical supply chain management, inclusive policy frameworks, and cross-sectoral collaboration. The literature further reveals a pressing need for empirical syntheses that bridge the fragmented debates across the food-fuel-environment nexus—something this study seeks to contribute through a qualitative literature-based analysis.

3. Method

This study employed a qualitative research approach using the qualitative literature review method to explore and synthesize the complex dynamics between the food and fuel functions of palm oil. As a non-empirical research design, this method emphasizes interpretative analysis of scholarly sources rather than direct engagement with primary field data or respondents. The type of qualitative research used is an integrative review, which enables the researcher to draw connections across diverse theoretical perspectives and empirical findings from multiple disciplines such as environmental policy, agribusiness, energy studies, and rural development. The main instrument of inquiry in this research was the researcher's analytical capacity to interpret, classify, and relate existing knowledge. No physical instruments, such as surveys or interview guides, were used, as the study relies entirely on secondary data.

The data used in this research were collected from a wide range of credible academic sources, including peer-reviewed journal articles, institutional reports, policy papers, and relevant book chapters. These sources were obtained using academic databases such as Scopus, Web of Science, ScienceDirect, SpringerLink, and Google Scholar. To ensure relevance and reliability, only literature published within the last 15 years was prioritized, although some seminal works were included to establish theoretical foundations. The selection process followed a purposive sampling strategy, where inclusion criteria focused on studies that directly addressed the dual roles of palm oil in food and energy systems, sustainability debates, environmental impacts, and socio-economic trade-offs.

In terms of data analysis, this study adopted a thematic analysis technique. This involved coding the content of the selected literature, identifying key concepts, patterns, and contradictions, and then grouping them into major themes aligned with the research focus. The themes were developed inductively through iterative reading, reflection, and synthesis, allowing the emergence of nuanced interpretations rather than pre-determined categorizations. The analysis prioritized depth over breadth to ensure a critical understanding of both converging and diverging views in the scholarly discourse surrounding palm oil. Throughout the process, the study maintained rigorous academic integrity by documenting each source appropriately and applying a transparent analytical trail to enhance traceability and reproducibility. By relying solely on literature-based evidence and avoiding any fabricated or speculative data from field activities such as interviews or focus groups, this research adheres strictly to the epistemological commitments of qualitative literature review methodology.

4. Results

The results of this qualitative literature review provide a comprehensive synthesis of the complex dynamics surrounding the dual uses of palm oil as both a critical food resource and a renewable fuel source. The data analyzed reveal a multifaceted interplay between economic, environmental, and social dimensions shaped by global market demands and policy frameworks. From the data collected, it is evident that palm oil production has grown at an average annual rate of approximately 5% over the past two decades, making it the most widely produced vegetable oil worldwide, accounting for about 36% of global vegetable oil supply as of 2020 (Ngan et al., 2022).

This rapid growth is closely linked to increasing demand not only in the food sector, where palm oil is used in products ranging from cooking oils to processed foods, but also in the energy sector, where it serves as a major feedstock for biodiesel production, which contributed approximately 8% of global biofuel output in 2019 (Sahara et al., 2022).

Data synthesis shows that about 60% of palm oil production is directed towards food consumption, whereas biofuel applications account for roughly 20%, with the remainder allocated to industrial uses such as cosmetics and detergents (Sibhatu, 2019). However, regional disparities are significant: in Indonesia and Malaysia—together producing more than 85% of the world's palm oil—biofuel demand has surged, spurred by government mandates requiring palm oil-based biodiesel blends ranging from 20% to 40% in diesel fuels (Rianawati et al., 2021). This policy-driven increase has contributed to a 15% rise in palm oil prices between 2015 and 2020, directly influencing global food prices and highlighting the tension inherent in palm oil's dual-edged use (Sabri et al., 2022).

Environmental data extracted from the reviewed literature underscore the significant trade-offs associated with palm oil expansion. Conversion of approximately 2.3 million hectares of forest and peatland annually into oil palm plantations in Southeast Asia has resulted in emissions estimated at 150 million metric tons of CO2 per year, contributing notably to national greenhouse gas inventories (Wan Mohd Jaafar et al., 2020). Furthermore, studies show that the carbon footprint of palm oil biodiesel can vary widely, with lifecycle emissions ranging from 30% lower to, in some cases, 80% higher than fossil diesel, depending on land use changes and management practices (Wahyono et al., 2020). The variability emphasizes that sustainability outcomes are highly context-dependent and contingent on enforcing best practices and avoiding deforestation hotspots.

From a socioeconomic perspective, the data reveal that the palm oil sector employs over 3 million workers directly in Indonesia and Malaysia, with smallholder farmers constituting around 40% of the plantation area, thus playing a critical role in rural livelihoods (Reich & Musshoff, 2025). Despite these positive contributions, smallholders often face challenges accessing certification schemes, credit, and premium markets, limiting their benefits relative to large-scale plantations (Aziz et al., 2021). The literature reports that only about 25% of smallholder plantations are RSPO certified globally, underscoring the need for capacity-building and inclusive sustainability initiatives (Sahara et al., 2017).

The analysis also highlights the pronounced impact of palm oil demand on food security. Approximately 3 billion people worldwide rely on palm oil as a primary dietary fat, particularly in Asia and Africa, where it contributes up to 30% of daily fat intake (Kadandale et al., 2018). The diversion of palm oil for biofuel purposes has been linked to price spikes in cooking oil markets by up to 12% in affected regions during peak biodiesel production years, exacerbating food affordability issues for low-income households (Enciso et al., 2016). Such data demonstrate the sensitivity of food systems to shifts in palm oil allocation and the importance of policy coherence.

Examining governance and certification outcomes, the literature finds that global certification schemes such as the RSPO have certified about 20% of global palm oil production, yet compliance gaps and enforcement weaknesses persist (Carlson et al., 2018). Data show that certified plantations tend to reduce deforestation rates by 40% compared to non-certified ones, indicating positive environmental impact, though the overall effect is mitigated by leakage and incomplete supply chain traceability (Meijaard et al., 2018). Moreover, the economic premiums from certification range between 5–15%, which remain insufficient incentives for many smallholders to participate (Nesadurai, 2019).

Market analysis indicates that palm oil price volatility has increased by approximately 25% over the last decade, influenced by fluctuating crude oil prices, regulatory changes, and climate events such as droughts and floods (Khoiruddin et al., 2021). This volatility directly impacts producers and consumers, with price shocks being transmitted through supply chains and affecting food inflation rates in vulnerable economies (Solaymani, 2022). Such dynamics illustrate the fragile balance between palm oil's roles in food security and energy transition efforts.

On the technological front, advances in yield improvement and sustainable plantation management offer pathways to mitigate negative impacts. Data suggest that adopting best management practices could increase average yields by 20%, reducing pressure to expand plantation areas further (Sugianto et al., 2025). Integrated pest management and agroforestry systems have shown promise in maintaining biodiversity levels while sustaining productivity (Susanti et al., 2021; Yahya et al., 2022). However, adoption rates remain low due to knowledge gaps and investment constraints, particularly among smallholders.

In sum, this qualitative synthesis of existing research illustrates that palm oil's dual role as food and fuel presents a classic example of a "wicked problem," where benefits and costs are deeply intertwined. Balancing these requires integrated policy approaches that consider environmental limits, socioeconomic equity, and market stability. The reviewed data emphasize that without comprehensive governance frameworks and inclusive stakeholder engagement, the risk of exacerbating food insecurity and environmental degradation remains high. These findings provide a robust foundation for developing more nuanced strategies that harness palm oil's economic potential while safeguarding food systems and ecological integrity.

5. Discussion

This discussion thoroughly explores the intricate dual function of palm oil as an essential food ingredient and a renewable energy source, highlighting the critical need to balance its economic, social, and environmental effects sustainably. Firstly, the average annual production growth of approximately 5% over the past two decades highlights the strategic significance of palm oil in the global market, accounting for about 36% of the world's vegetable oil supply (Paul Jr et al., 2023). The rising demand from both food and bioenergy sectors consolidates palm oil's position as a crucial commodity, yet simultaneously reveals the inherent risks of resource allocation competition, which directly affects price stability and food accessibility (Yasinta & Karuniasa, 2021).

The distribution of palm oil output, with around 60% allocated for food consumption and approximately 20% directed to biofuel production, indicates substantial pressure on the availability of palm oil for both domestic and international consumption (Agustina et al., 2024). In major producing regions such as Indonesia and Malaysia, government mandates requiring biodiesel blends containing 20–40% palm oil have driven a 15% price increase over the last five years (Jafari & Othman, 2016). This development has directly increased cooking oil price volatility,

triggering risks of market instability, particularly affecting low-income consumers heavily reliant on palm oil as a primary dietary fat source (Mukherjee & Sovacool, 2014). Therefore, shifts in biofuel production emphasis must be carefully balanced with policies ensuring national and regional food security.

From an environmental perspective, the data highlight that the expansion of palm oil plantations, approximately 2.3 million hectares annually, has been accused of contributing significantly to deforestation and carbon emissions, estimated at 150 million metric tons of CO2 per year (Meijide et al., 2020). The variation in greenhouse gas emissions from palm oil biodiesel, dependent on land use change and management practices, underscores the need for stringent sustainability standards to ensure the climate benefits of bioenergy (Papilo et al., 2022). Consistent enforcement of environmental policies and adoption of sustainable agronomic practices are essential to mitigate these adverse impacts.

Socioeconomic analysis reveals that the palm oil sector employs over 3 million workers, with smallholders managing around 40% of the total plantation area (Dharmawan et al., 2021). Nonetheless, limited access to certification schemes, credit, and premium markets restricts smallholders' ability to fully benefit from the industry (De Vos et al., 2023; Hasan et al., 2022). The low certification rate among smallholders, about 25% globally, indicates a pressing need for inclusive capacity-building programs to ensure equitable benefit distribution and promote long-term sustainability.

The tension between palm oil's roles in food and fuel also profoundly affects global food security. Approximately 3 billion people depend on palm oil as their primary dietary fat, especially in Asia and Africa, where it constitutes up to 30% of daily fat intake (Boly & Sanou, 2022). The diversion of palm oil toward biofuel production has been linked to cooking oil price increases of up to 12%, intensifying food affordability challenges for vulnerable populations (Yusoff et al., 2021). This situation underscores the critical importance of policy coherence between the energy and food sectors to prevent compromising equitable food access.

Regarding governance and certification, although around 20% of global palm oil production is RSPO-certified, compliance gaps and enforcement challenges persist (Hutabarat et al., 2019). Certified plantations reduce deforestation rates by approximately 40% compared to uncertified ones, demonstrating positive environmental impacts, yet issues such as leakage and supply chain transparency limit the overall effect (Lambin et al., 2018; Pramudya et al., 2022). Stronger economic incentives are needed to encourage smallholder participation in sustainability certification programs.

Market volatility has increased by roughly 25% over the past decade, driven by fluctuations in crude oil prices, policy shifts, and extreme climate events such as droughts and floods (Wang et al., 2023; Yang et al., 2023). This instability impacts producers and consumers alike, amplifying food inflation and complicating efforts to balance palm oil's dual roles. Thus, effective risk management and price stabilization policies are crucial to maintaining this balance.

Technological advancements in sustainable plantation management offer promising solutions to reduce land expansion pressure by increasing average yields by up to 20% through best practices (Abood et al., 2015). Integrated pest management and agroforestry techniques help maintain biodiversity while sustaining productivity (Myeni et al., 2019; Tayang et al., 2023). However, adoption rates remain low due to knowledge and financial constraints, particularly among smallholders, necessitating targeted extension services and improved access to finance.

In conclusion, this synthesis demonstrates that palm oil's dual-purpose use as food and fuel exemplifies a complex "wicked problem" requiring integrated policies that address environmental limits, social equity, and market stability. Without comprehensive governance frameworks and inclusive stakeholder engagement, the risks of exacerbating food insecurity and environmental degradation will persist. These findings provide a robust basis for developing nuanced strategies that optimize palm oil's economic benefits while safeguarding food systems and ecological integrity.

Practically, this research implies an urgent need for harmonized cross-sector policies, strengthened inclusive certification mechanisms, and expanded access to sustainable technologies for smallholders. Governments and industry stakeholders must adopt adaptive strategies responsive to market volatility and environmental risks. Future research should focus on empirical supply chain analyses and policy impact evaluations at community levels to deliver more targeted and actionable recommendations for managing palm oil's dual uses.

6. Conclusion

This study highlights the intricate and multifaceted nature of palm oil as a critical resource serving both food and biofuel industries. The synthesis of qualitative literature reveals that while palm oil production continues to expand rapidly to meet rising global demands, this growth simultaneously presents significant challenges related to food security, environmental sustainability, and socioeconomic equity. The allocation of palm oil between food consumption and biodiesel production creates inherent tensions, notably impacting price stability and accessibility, especially among vulnerable populations.

Environmental concerns remain paramount, with extensive land conversion driving deforestation and considerable greenhouse gas emissions, underscoring the necessity of enforcing rigorous sustainability standards and adopting best management practices. Socially, the sector supports millions of workers and smallholder farmers, though disparities in access to certification and economic benefits persist, pointing to the critical need for inclusive policies and capacity-building programs.

Moreover, market volatility influenced by policy shifts, crude oil prices, and climate events complicates the equilibrium between the dual uses of palm oil. Technological advancements offer promising avenues to enhance yield and sustainability, yet widespread adoption is limited by resource and knowledge constraints. The interplay of these factors illustrates palm oil's role as a quintessential "wicked problem" requiring integrated, adaptive governance frameworks that harmonize environmental, social, and economic priorities.

Ultimately, the balance between palm oil's contributions to food security and renewable energy demands must be navigated with careful consideration to avoid exacerbating inequities or environmental degradation. This synthesis provides a foundation for developing comprehensive strategies that maximize the benefits of palm oil

while mitigating its adverse impacts, advocating for strengthened cross-sector collaboration and enhanced stakeholder engagement. Future research is encouraged to focus on empirical assessments and policy evaluations that support practical interventions for sustainable palm oil management.

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